Summary Report ICAR-504-1S

The International Center for Aggregates Research is funded by the Aggregates Foundation for Technology, Research, and Education (AFTRE); the National Stone, Sand, and Gravel Association; funds from The University of Texas at Austin and Texas A&M University; and contributions from the aggregates industry.

INTERNATIONAL

ICAR

CENTER FOR AGGREGATES RESEARCH

SENSITIVITY ANALYSIS OF FLEXIBLE-PAVEMENT RESPONSE AND THE AASHTO DESIGN GUIDE TO PROPERTIES OF UNBOUND LAYERS

PROBLEM STATEMENT

Unbound granular materials generally compose the base and subbase layers in road pavements. The granular materials distribute the load through aggregate contacts to a level sustainable by the subgrade. Pavement design and analysis often describe the base and subbase layers using the resilient modulus, which is the ratio of the dynamic-resilient stress to the dynamic-resilient strain. The resilient modulus represents a power function of the sum of the principal stresses. However, this model has serious limitations because it neglects shear strain's effect and it only works at low strain values in granular-materials characterization.

Deviatoric stress should be included in resilient-modulus evaluation. Researchers developed a model that relates the resilient modulus to the sum of principal stresses and the octahedral stress.

Recent studies show that the unbound granular layers exhibit cross-anisotropic properties not accounted for in field models. Also, the proposed AASHTO 2002 Design Guide excludes them.

Cross-anisotropic behavior results from the aggregates' preferred orientation in unbound layers and compaction forces. Thus, base and subbase layers are stiffer in the vertical than in the horizontal direction. Using stiffness's directional dependency better describes the unbound layer's dilative behavior and also reduces/eliminates the unrealistically significant tensile stresses predicted in granular bases using isotropic models. The influence of using different response models (isotropic vs. anisotropic and linear vs. nonlinear) on the performance predictions of asphalt pavements needs further investigation. In addition, the sensitivity of the proposed AASHTO 2002 guide to unbound layers' properties needs urgent evaluation prior to the use of this guide in practice.

OBJECTIVES

- Conduct a comparative analysis of flexible-pavement response using different models for unbound pavement layers: nonlinear isotropic and nonlinear anisotropic. Next, compare the results from different models to experimental measurements from the AASHO Road Test.

- Evaluate the permanent deformation and fatigue cracking calculated using the performance models in the proposed AASHTO 2002 design guide. These distresses are calculated using pavement responses computed from linear isotropic, nonlinear isotropic, linear anisotropic, and nonlinear anisotropic models for the unbound aggregate layers.

- Conduct a sensitivity analysis of the proposed AASHTO 2002 guide to the properties of unbound pavement layers.

FINDINGS

Sensitivity Analysis of Pavement Response Using Different Structural Models and Comparison with AASHO Road Measurements

A finite-element program helped to calculate deflections of sections representative of the AASHO Road Test. We compared these calculations to the field experimental measurements, finding:

■ The ratio of the horizontal modulus to the vertical modulus models anisotropy. The error between predictions and measurements decreases as anisotropy increases.

■ The FEM (Finite-Element Model) predictions correlate best with experimental measurements when the horizontal modulus was about 30% of the vertical modulus.

■ The predictions matched the AASHO measurements in the fall better than in the spring. As reported in the AASHO experiment, distresses detected in the spring might have caused the response to deviate from the elastic solutions used in the FEM.

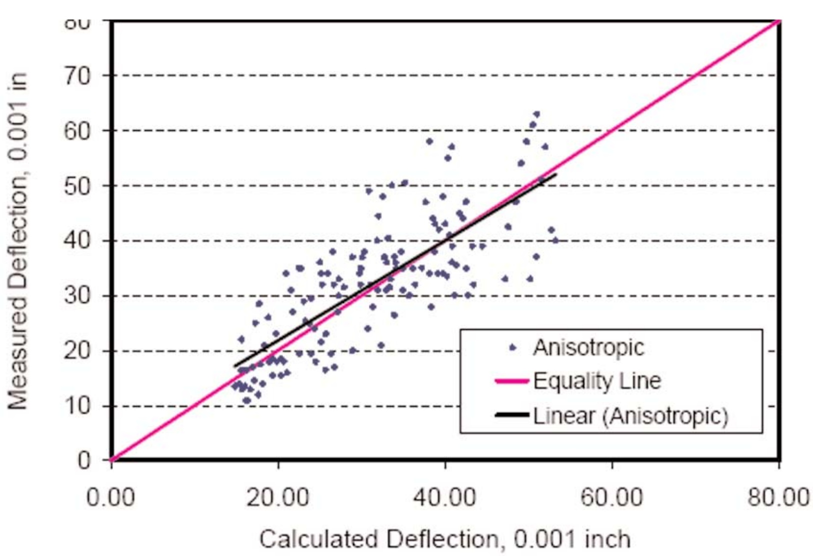

FIGURE 3 Measured versus predicted deflections using anisotropic properties with ($n = 0.3$, $\mu = 1.5$) for the Fall season.

Analysis of Flexible-Pavement Rutting and Fatigue Cracking Using Isotropic- and Anisotropic-Response Models

We calculated permanent deformation and fatigue cracking based on the mechanistic-empirical models used in AASHTO 2002 with isotropic and anisotropic material properties, finding:

■ For the base and asphalt layer, the permanent deformation obtained using the anisotropic model always exceeds that using the isotropic model.

■ In the subgrade, the permanent deformation obtained using the isotropic model exceeds that for the anisotropic model using the regression equations from Tseng and Lytton. However, the permanent deformation using the isotropic model can be more or less than that calculated using the anisotropic model when using the regression equations used in the AASHTO 2002.

■ The total permanent deformation using the isotropic model can be more or less than that for anisotropic model when using the regression equations from Tseng and Lytton. However, the total permanent deformation using the anisotropic model exceeds that calculated using the isotropic model when using the AASHTO 2002 equations.

■ The fatigue life predicted using the nonlinear, anisotropic approach exceeds the life predicted using the nonlinear isotropic approach. This observation can explain part of the rift between the laboratory fatigue life calculated using the isotropic analysis and field fatigue life. This shift factor drops when using anisotropic properties.

Sensitivity Analysis of the AASHTO 2002 Design Guide

■ The sensitivity-analysis results show that the base modulus and thickness significantly influence the international roughness index and longitudinal cracking.

■ Base properties influence alligator cracking about half as much as longitudinal cracking.

■ All the results show that base properties have almost no influence on permanent deformation. These findings apply to the three climatic zones, two asphalt-binder grades, and three traffic levels

The information in this summary is detailed in research report ICAR 504-1, Sensitivity Analysis of Flexible-Pavement Response and AASHTO Design Guide to Properties of Unbound Pavement Layers, *by Sanaa Ahmad Masad and Dallas N. Little.*